

# **REPORT ON THE INTERNATIONAL WORKSHOP “RIVER DELTAS: EVOLUTION, ENVIRONMENTAL CHALLENGES AND SUSTAINABLE MANAGEMENT”**

**jointly organized by**

**the Romanian National Institute of Marine Geology and Geo-ecology – GeoEcoMar  
and US Army Corps of Engineers**

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## **1. Introduction**

*Definition*<sup>\*</sup>

*“The most important landform produced where a river enters a body of standing water is known as a delta. The term is normally applied to a depositional plain formed by a river at its mouth, with the implication that sediment accumulation at this position results in an irregular progradation of the shoreline. Their evolution and shapes are depending on (1) characteristics within the drainage basin that provides the sediment (climate, lithology, tectonic stability and basin size); (2) properties of the transporting agent, such as river slope, velocity, discharge and sediment size; and (3) energy that exists along the shoreline, including factors such as wave characteristics, longitudinal currents and tidal range. The combination of these numerous variables tends to create deltas that occur in a complete spectrum of form and depositional style.*

*Deltas are distributed over all portions of the Earth’s surface. They form along the coasts of every landmass and occur in all climatic regimes and geologic settings.”*

As final parts of river courses towards the seas and oceans, deltas are under the influence of both rivers and seas. This is why, for a better understanding, they should be considered as systems of large rivers – deltas – coasts – seas/ocean macro-systems. Being at the contact between land and sea, deltas can be considered as one of the most reactive and frail continental systems, as are subject to swift changes at any variation of rivers and/or seas forcings.

During the past century, deltas (as well as the other components of the river-delta-coast-sea macro-systems) have been subject to ever increasing pressures from the explosive development of humankind. Drastic changes in land use (towards urbanization as well as agriculture), overexploitation of natural and living resources and the blocking of the natural evolution because of damming/embankments and changes in channels` courses

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<sup>\*</sup> Encyclopedia Britannica

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are only a few examples of the ways humans altered the deltaic systems. As a result, most of the deltas worldwide have been subject to degradation which, in the end, will negatively impact the future development of neighboring human communities. There are just a few happy cases when deltaic management proved to be successful, and one of the main causes of failure is the lack of an integrated planning of management in all the systems of the river-delta-coast-sea macro-system.

This is why new integrated management and scientific plans should be developed for the River-Delta-Coastal System, aiming at the Sustainable Development of these areas. A re-evaluation of the state of knowledge concerning the deltas of part of the River-Deltas-Coastal systems also appears to be a top priority, as it represents the basis of any future integrated management and sustainable development plan.

## **2. Management challenges**

As previously stated, deltas should be considered, in terms of processes and management, as a part of a more complex River-Delta-Coast System.

It is important to recognize that deltas are equilibrium landforms, but they are also landforms that are dynamic: they respond to changes in water and sediment fluxes, and are characterized by an ability to evolve through time. However, although our knowledge of individual components, or sub-systems, is in many cases adequate, if not good, it tends to be formulated in a way that makes it difficult to identify true inter-relationships between variables. For example, deltas are to varying degrees subsidized by the wider catchment, whilst increasingly they provide a number of tangible benefits (both locally and globally).

It appears thus of major importance that a major step forward should be to reconsider the way definitions are formulated both for all parts of the river-delta-sea systems, in a manner that helps the better understanding of the natural and human induced processes in those systems. An overall conceptual framework needs to be developed, and a draft is presented in appendix 1.

Pressures (both anthropogenic as well as natural, at smaller as well as wider scales) should also be identified for the river-delta-sea systems, both for the system as a whole and for all its components. This goal is of uppermost importance when trying to identify critical issues affecting the systems' state of sustainability.

Management plans that try to reach sustainability in deltaic areas should also try to answer the following questions:

- How capable is the system in terms of sustaining development or other anthropogenic changes?
- How much non-natural activity can the system sustain without adverse effects?
- How much of a change from the natural condition are we willing to allow?

To address these distinct attributes, it is necessary to identify inter-relationships between the socio-economic processes and the physical-biological system, as well as connections

within the various parts of the system, in order to determine the effects of any disturbance, or the implications of changes in key variables.

During the workshop, the following management principles and objectives were proposed:

- Main objective of management is to have a sustainable delta, i.e. to establish a balance between the socio-economic and the natural systems;
- Management of the delta means management of the entire river basin;
- Sustainable management should be based on system functioning;
- There is a need to understand that deltas develop under sustainable sea levels & sustainable sediment regimes and develop as open systems that we should not try to (over)engineer and restrain. The dynamic nature of deltas must be respected, therefore there is a need to avoid fixed solutions as much as possible.
- Delta management must be adaptive, in order to accommodate specific needs of individual deltas. Examples regard different management approaches between deltas that are natural biosphere reserves, highly populated deltas (e.g. Asian deltas), deltas where economic activities are already very developed (but where economic development should be allowed at sustainable levels).
- Management should deal with the multiple use of deltas and try to reach sustainable and un-conflicting levels for each of the uses.
- Restoration requires that we define the original condition or define an acceptable end state (restoring function or a critical portion of the function)
- Development of Sustainable Delta management plans should be made with the involvement of all significant stakeholders and decision makers, as well as with representatives of the local population.
- The success of the Management plan should be oftenly assessed and, when necessary, adapted to the newly identified requirements.

Due to its characteristics (it should deal with River-Delta-Coast systems), Delta Management also needs to address:

- Interstate and transnational issues
- Financial issues
- Science coordination – as research is done by multidisciplinary teams
- Communication of science to policy makers

### **3. Assessing the state of our understanding**

### **3.1. Critical Processes**

Global climate change in combination with human activities will directly affect deltas potentially producing catastrophic change on a decadal scale. If /when collapse occurs – the effects will be catastrophic. Even more, it must be considered that, as we are living times of real and growing energy scarcity, deltaic ecosystem services provide an enormous subsidy for the global economy.

#### **Concepts**

As mentioned in the previous chapter, it was agreed upon the fact that a new, "whole system" approach or framework must be considered, that should take into account both natural and human processes. This system should be considered to be open/non-linear.

There is a need to establish hierarchical processes through the development of conceptual models, to identify critical processes which need to be understood as well as the system's sensitivity/susceptibility to change.

#### **Reference conditions**

In order to achieve the management goals, it is very important to define reference conditions for the delta systems. It is thus necessary to establish a potential theoretical reference, against the background of functioning parts of the system.

#### **Knowledge gaps**

At the present there is a fragmentation of knowledge in different disciplinary compartments. These gaps and questions still to be answered and are presented below:

- Gaps in the function and structure of the different components of the deltaic system.
- Need a better understanding of the interaction between different factors controlling the functioning of the system (especially at the interfaces).
- What are the essential structural and functional elements needed to ensure ecosystem services?
- Which is the cost of loss of certain ecological functions, compared with benefits of investments?
- How soon could collapse occur, and what can we do to prevent this?

In the meanwhile, it was established that there is a need for more analyses and interpretation of data already at hand, to make the transition from a "picture" to the "movie" and that more data are required for establish reference conditions.

Suggestions of what should be developed or better approached in order to bridge the knowledge gaps about the deltaic systems are presented below:

- Development of new technologies for the study of processes throughout the system.
- More effective use of remote imaging and seismic.

- More detailed and precise knowledge on subsidence (due to tectonics and sediment loading, sediment compaction, as well as due to extraction of oil and water) and sea level change (eustatic, global warming, subsidence etc.).
- Improve knowledge of sediment dynamics and budgets, throughout the system, which may require standardized data collection. Reference site(s) per systems. Comparison of available technologies for measurement and estimation?
- Establish the necessary sediment supply to maintain the dynamic equilibrium of geomorphology
- More sophisticated landscape models needed. Interaction with the coastal process modelers is required.
- Need to establish optimal erosive controls - protective structures are the last option, but aren't they sometimes necessary?
- What are the interactions among vegetation, sediment retention, accretion? Coupling of habitat models with geomorphology, evolutionary models.
- Can biotopes be used - i.e. physical environments (if you build it, they will come). Create biotic diversity in time and space.
- Ecological requirements of resident and migrant species - life stages?
- Status, evolution, and prediction of invasions by species. Need more advanced techniques for control of invasives.
- Sea Level Rise - how do we predict? how can we mitigate?

The research results need to be effectively communicated with the managers, decision makers, stakeholders and the general public. This is why there is a need to identify inter-relationships between socio-economic processes and the physical / biological system which can be incorporated into a DSS to determine the effects of any disturbance. All communications mechanisms should be used for this transfer of information. When developing a sustainable management plan for a delta system, stakeholders must be involved in all stages of planning.

#### **4. Setting a research agenda**

It was considered that whilst in many cases we have adequate understanding of individual processes that are applicable to deltas generally, a process of review and revision is required:

- to refine key concepts and summarise conceptual models; and
- to improve the quantifiable system descriptors that are necessary to achieve a viable DSS.

Ultimately, this will enable us to determine how soon collapse might occur in individual deltas, and what actions are required to prevent this. At the same time, it is essential to

document and quantify the many ecosystem services performed by river deltas and the anticipated effects of climate change and energy scarcity. In essence, the approach should seek to replicate the activities of the Inter-governmental Panel on Climate Change (IPCC), but for deltas, to achieve the goal of integrated delta management. This might fall within the scope of an Inter-governmental Panel on Delta Sustainability (IPDS) (N.B. a cross-chapter case study on megadeltas has been produced for the 4<sup>th</sup> IPCC report).

It is only by doing so, that we can expect wider social and political support for the conservation and maintenance of deltaic wetlands, although this will require improvements in communication (to enable the cascade of information in different directions), and transparency (to ensure that the rationale for difficult management decisions is recognised).

A series of ideas resulted during the workshop are presented in Appendix 2.

## Appendix 1. Conceptual framework of deltaic systems

- Lower river valleys and floodplains as well as deltas experience a flood-pulse events
- Define system and subsystems
  - *Watershed* (drainage basin and fluvial system above delta plain)
  - *Delta plain*: area from behind the barriers up to the head (apex) of the delta. The delta plain is usually split into fluvial (upper) and marine (lower) parts. The head (apex) of the delta can be defined in different ways:
    - Includes channels, natural levee ridges, wetlands, and shallow water areas
    - Salinity distribution or salinity gradient
    - Tidal influence
    - Historic shoreline
    - Beginning of distributary channels
    - Others
  - *Delta fringe*:
    - Higher energy zone of delta that is often characterized by coarser sediments
    - Outer limit of estuarine plume?

## **Appendix 2. Setting a research agenda**

### **1. Unifying Concepts**

- Build on existing models and concepts that we already have – a cascading system of downstream movement
- Sediment and material budgets, sources and sinks – both as a cascading system with downstream gradients
- Watershed management – linkages extend through the whole system (tracking sediment and water and effects on trophic structures)
- Need for conceptual / heuristic model – and sensitivity to change – that offer testable hypotheses.
- Structure and function of this whole system and components that live by compromise

### **2. Method development / integration**

- Integrating tools and descriptions
- Adapting tools from other disciplines
- Develop approaches and methodologies for measuring and describing multi-scale properties; new paradigms for higher levels of integration and higher (larger?) scales
- Can we use Remote Sensing (RS) for validation of a 2<sup>nd</sup> generation of data?
- Appreciation of subjects where RS works and where not
- Using multi-layer GIS; integration of information available in different layers

### **3. Reference systems / indicators**

- Need to be selected very carefully since these are highly dynamic areas
- need for indicators (system) of state and indicators of change
- (Uneven) Distribution of benefits and impacts over the system; quantification of these benefits and impacts
- Quantifying ecosystem services in costs for comparison; environmental economics of non-market issues
- What components of the natural system should be maintained for functioning? (since we cannot maintain the natural state)

#### **4. Predictive Capabilities**

- Necessary to have long-term datasets – preferably augment with previously collected datasets
- Challenges in model integration – particularly between system components geographically and functionally – particularly linking biological models with physical models
- Need landscape models – integrate GIS technology
- Benchmarking models to key data sets
- May develop nested models
- Clearly articulate purpose of models and define appropriate applications
- Assess model sensitivity